Complexities associated with using temperature to infer biodegradation rates

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USGS
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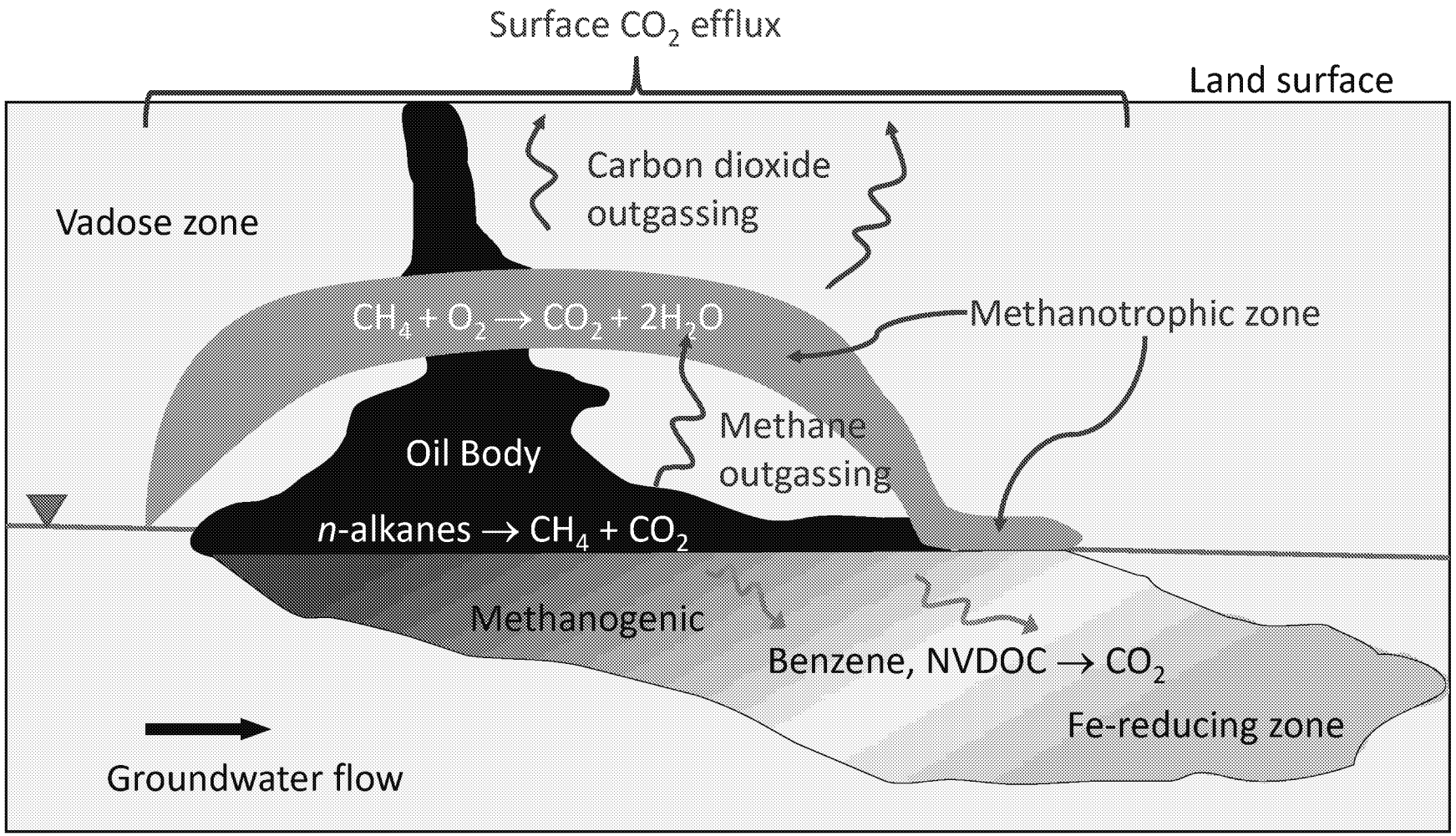
Bemidji Site conceptual model



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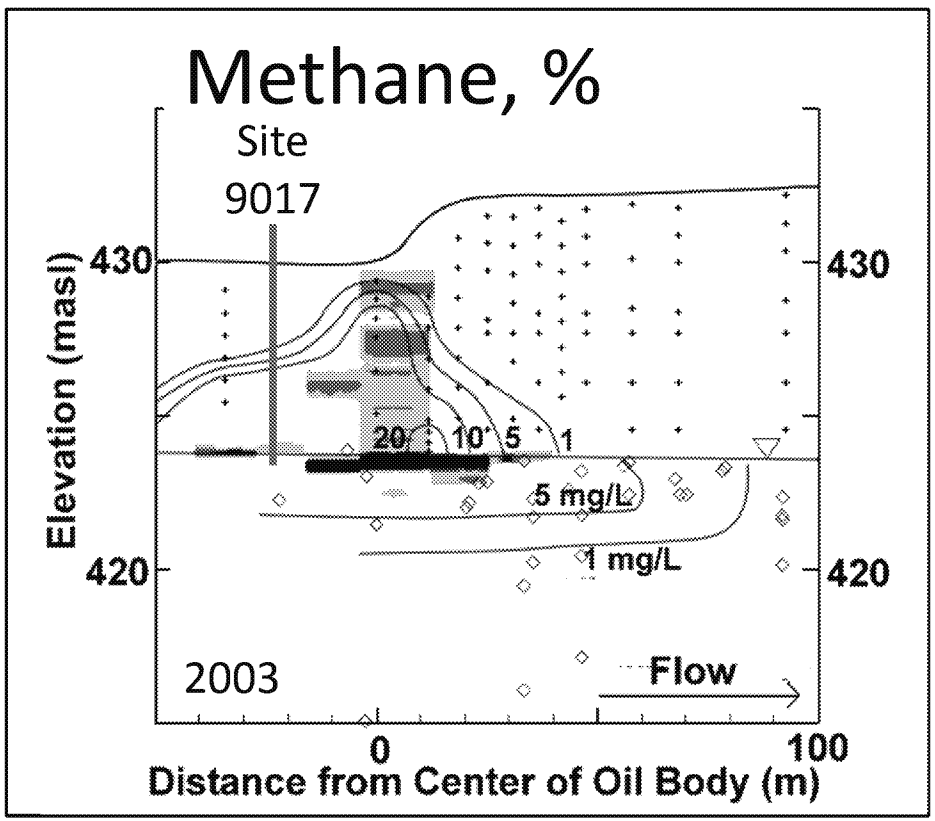
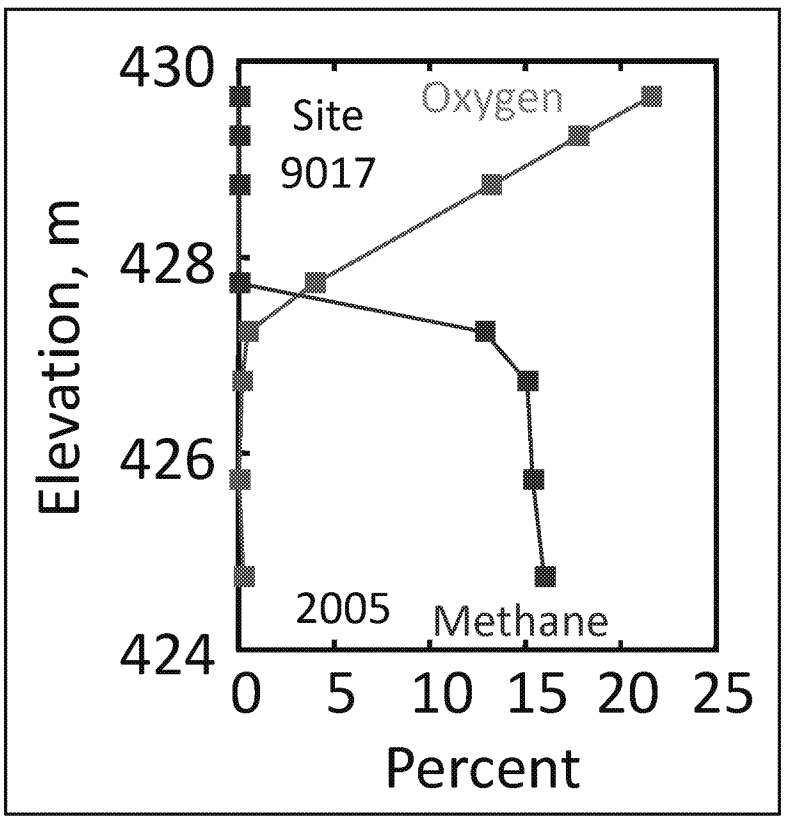
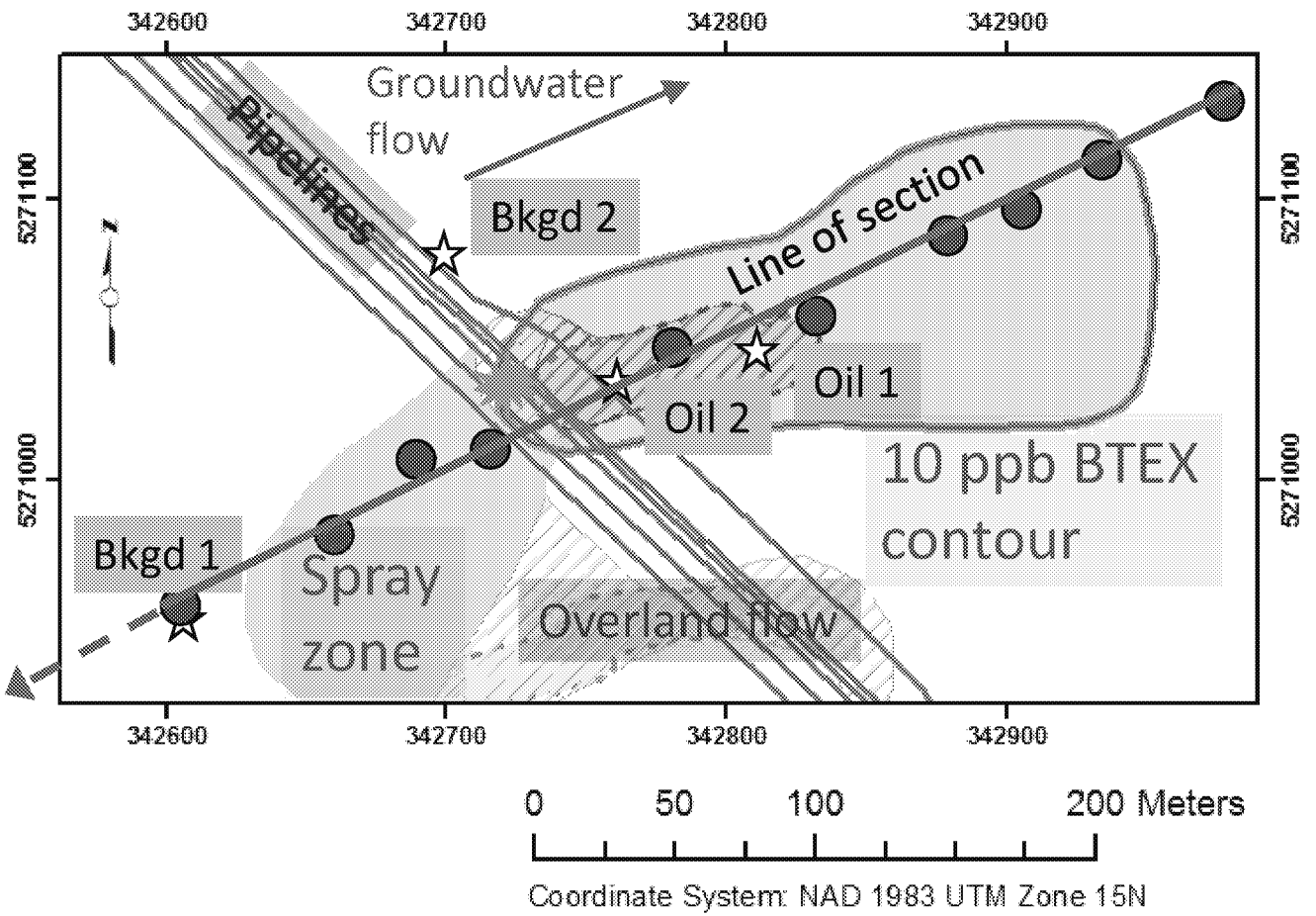
The Bemidji conceptual model is supported by data

- This conceptual model is also presented in Askarani et al., 2018, doi: 10.1111/gwmr.12286
- Sweeney and Ririe, 2014, doi: 10.1111/gwmr.12064 argued heat source from aerobic reactions but present only two oxygen profiles and no other gas data
- No known published articles have demonstrated that heat can be used to locate LNAPL bodies





Temperatures were measured at sites along a transect at Bemidji

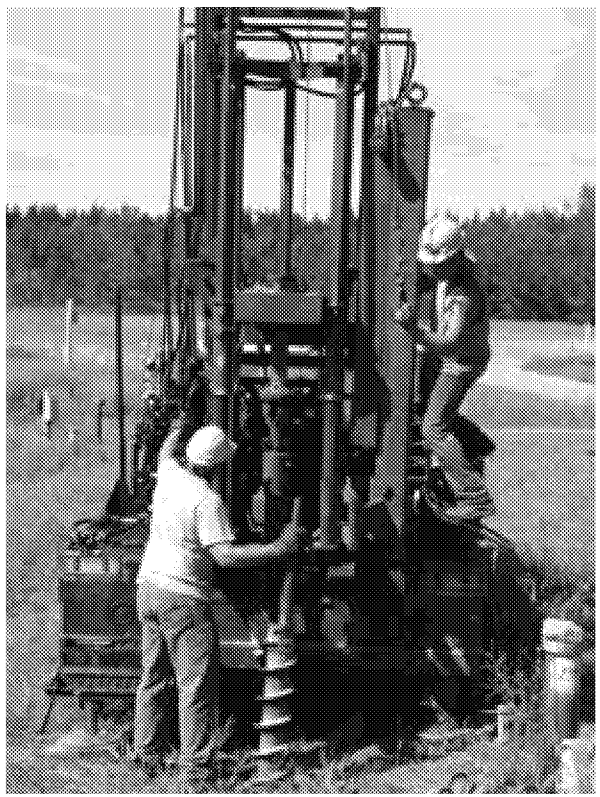


☆ Water-filled tubes with loggers in unsaturated zone

● Wells with loggers at 0.5 and 4 m below water table

Temperatures were measured either in water-filled tubes or in wells

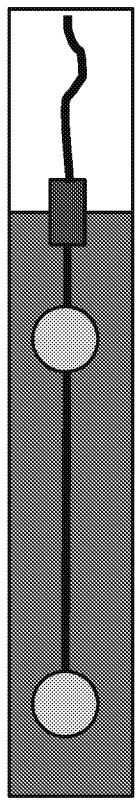
Temperature measurements



Drill rig

Installed water tube

Temperature logger



Well logger

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Average temperatures on normalized depth scale

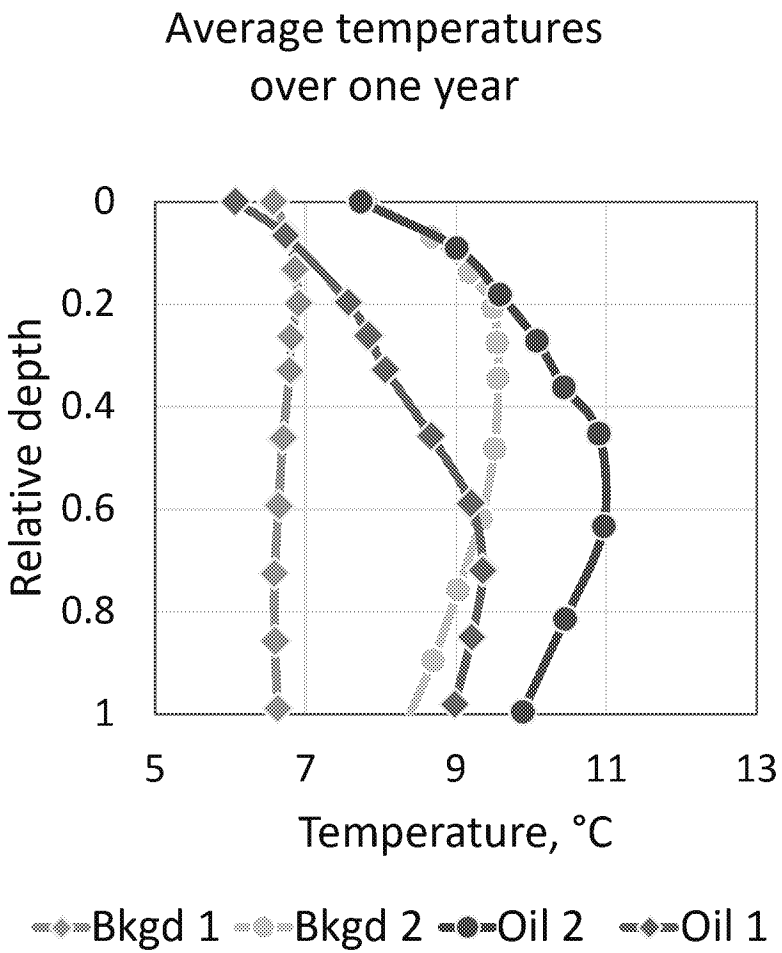
Bkgd 1

- Constant temperature from surface to water table
- The average groundwater T equals the average surface T
- Used to normalize Oil 1 because neither is affected by the pipeline

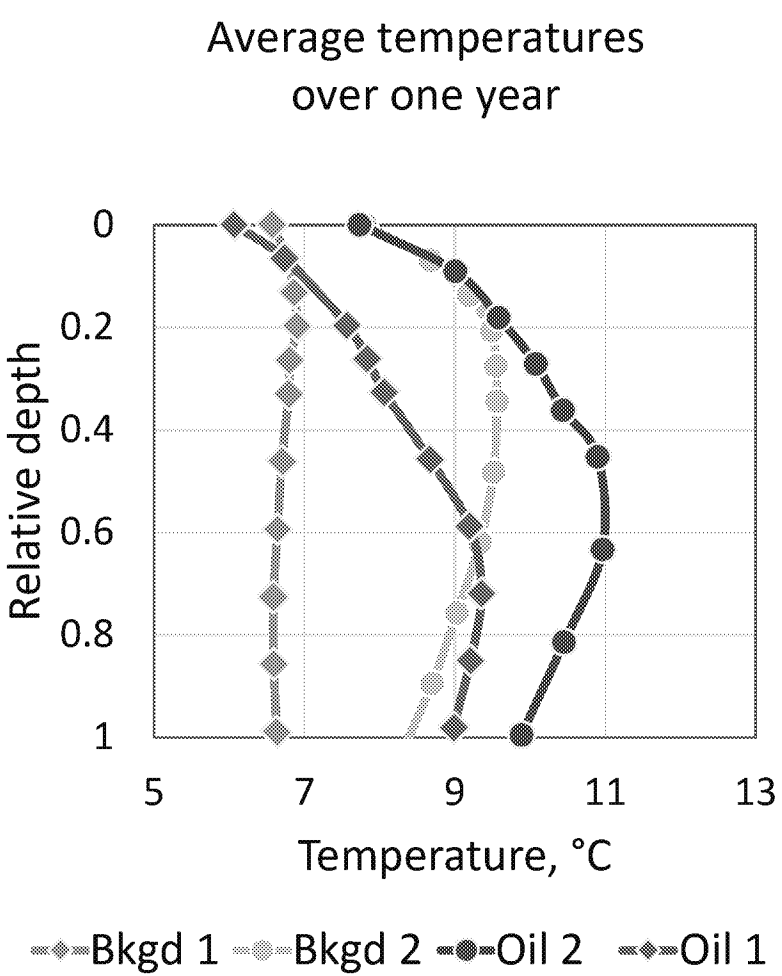
Bkgd 2

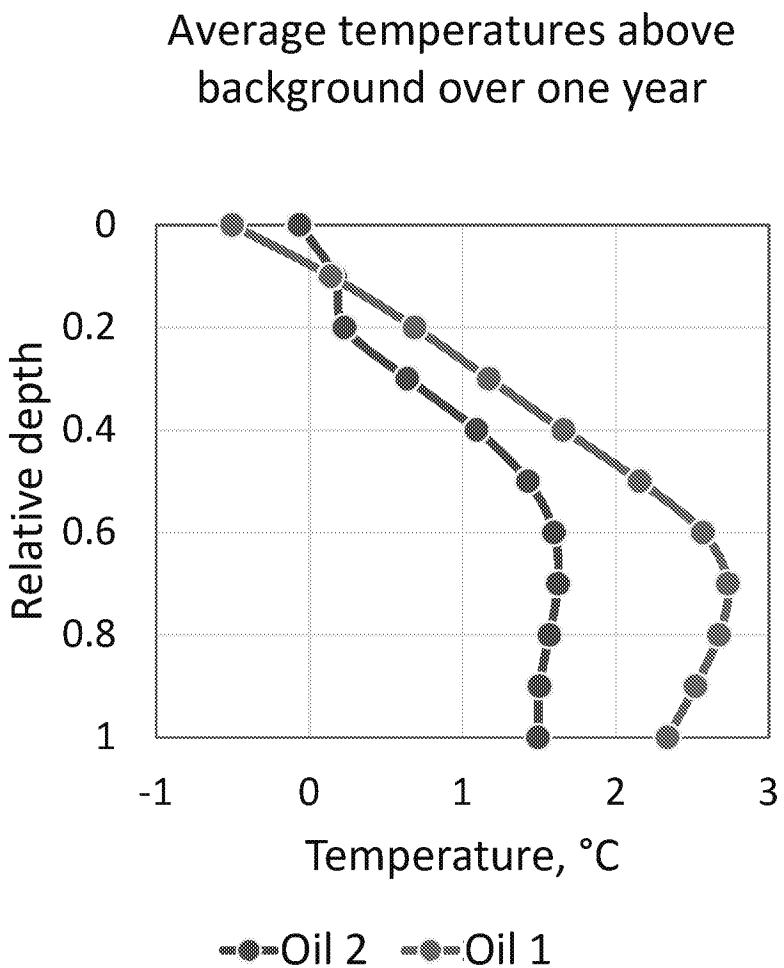
- T is elevated over Bkgd 1 due to heat from the oil pipeline
- Used to normalize Oil 2 since both Bkgd 2 and Oil 2 are 5 m from the pipeline
- If Bkgd 1 was used, the rates would be artificially high

➢ Askarani et al. (2018) also state that multiple background sites may be needed

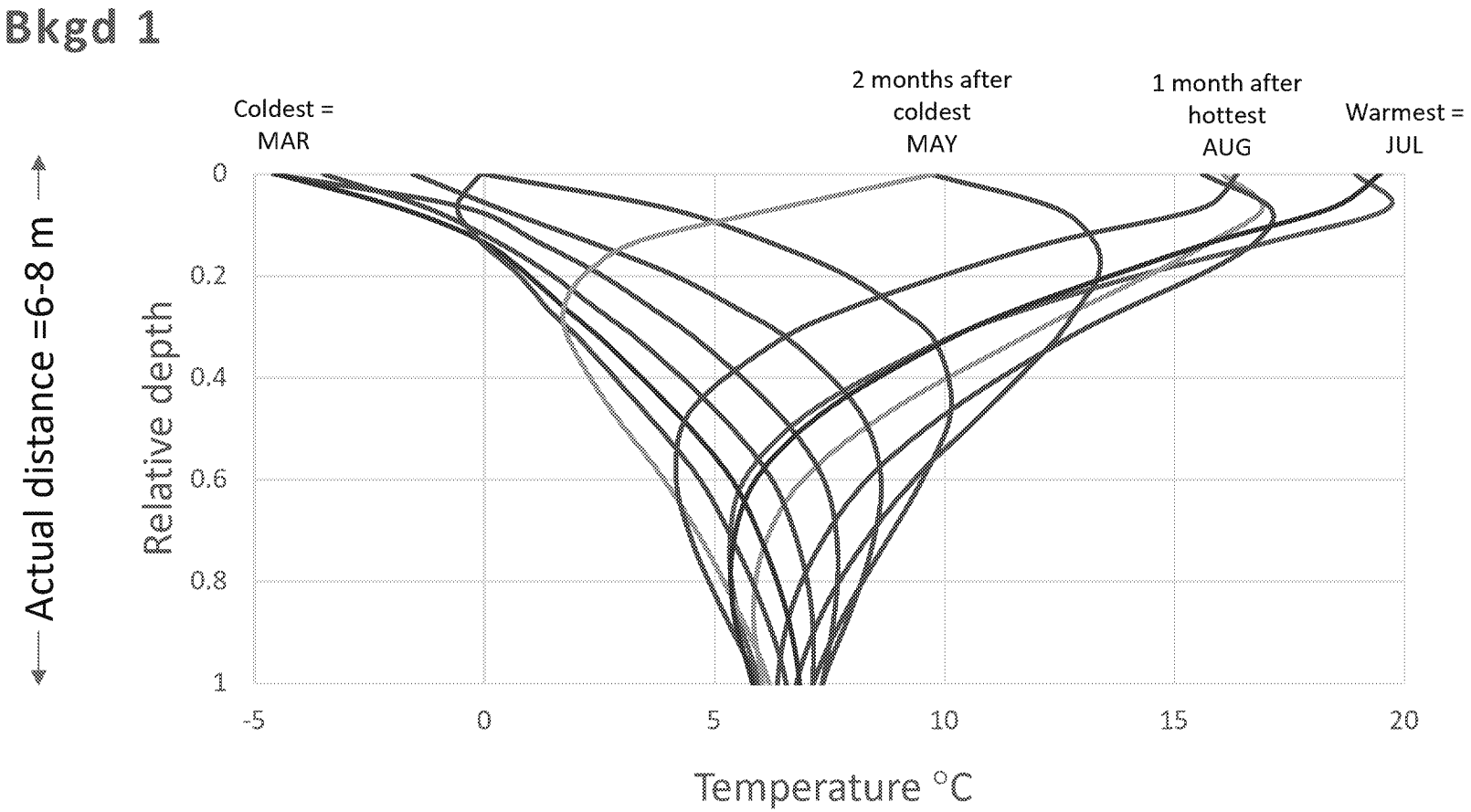


Temperatures normalized to annual averages show microbial heating





Bemidji unsaturated zone temperature data for one year

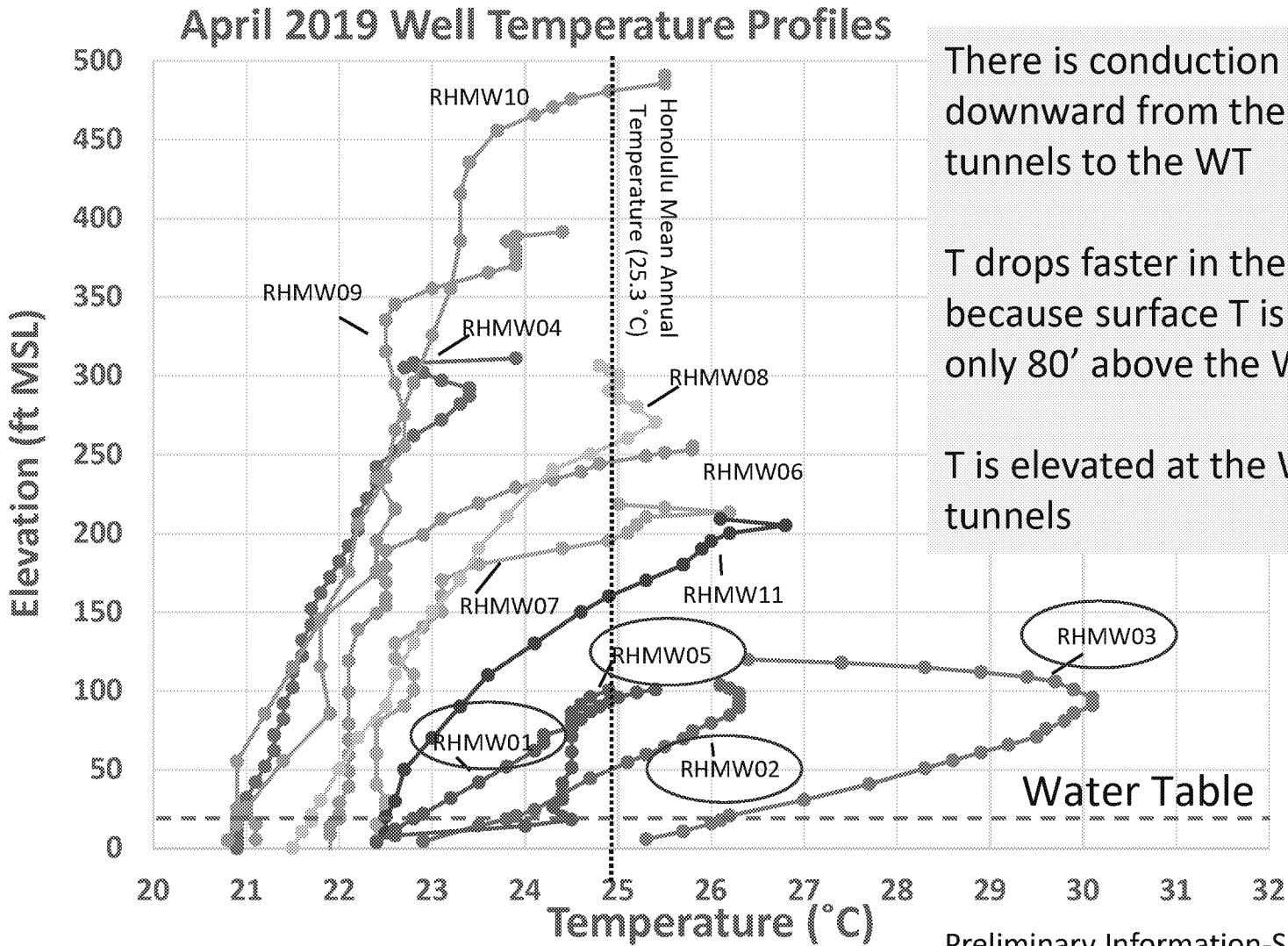


In comparison, Red Hill temperature profiles were measured in

Sept = 1 month after hottest Honolulu month which is August

April = 2 months after coldest Honolulu month, which is February

At Red Hill groundwater T=21° is 4.3 degrees C colder than mean annual surface T=25.3°



There is conduction of heat downward from the surface and tunnels to the WT

T drops faster in the tunnels because surface T is maintained at only 80’ above the WT.

T is elevated at the WT below the tunnels

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The water table below the site is warmer complicating the use of an outside well for background

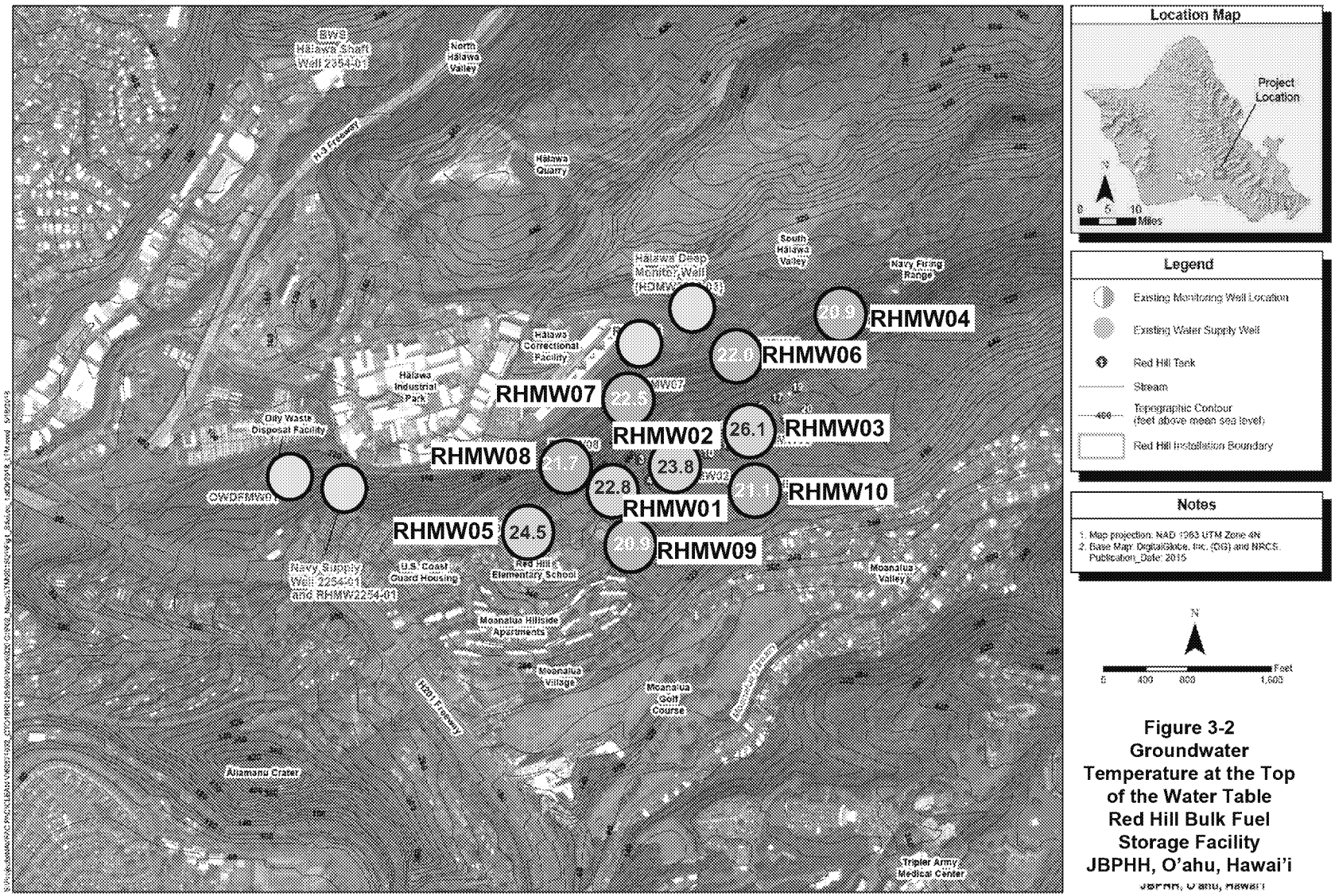

Figure 3-2
Groundwater Temperature at the Top of the Water Table
Red Hill Bulk Fuel Storage Facility
JBPHH, O'ahu, Hawai'i

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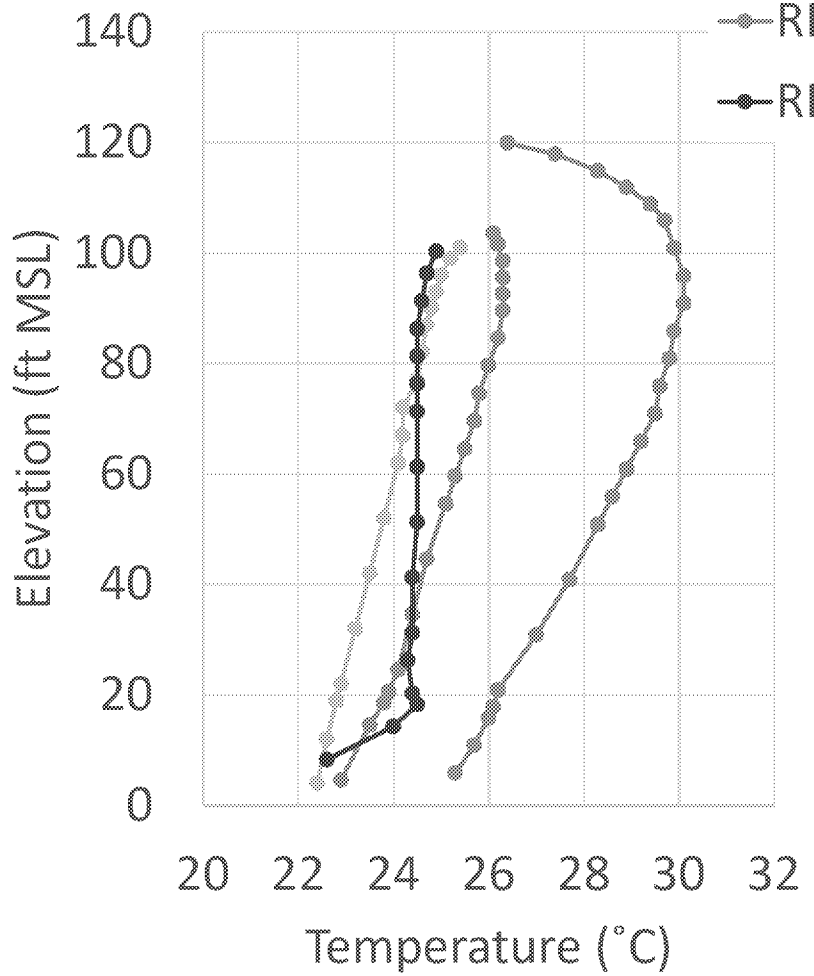
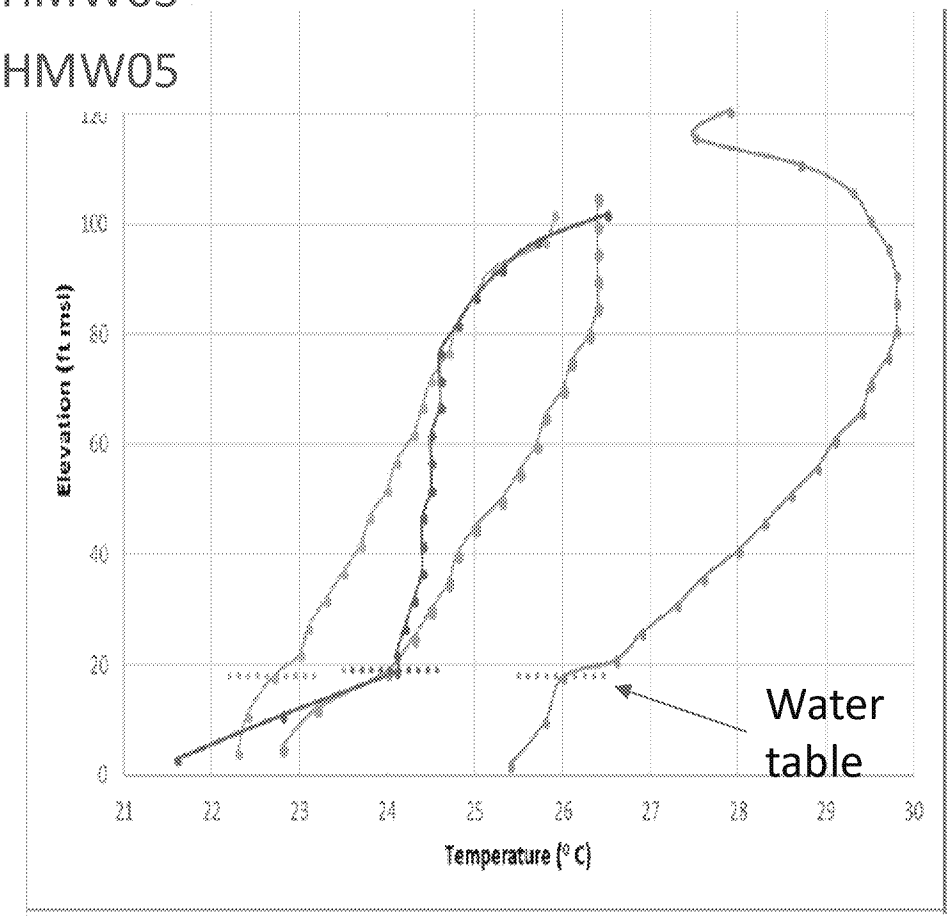
Viability of RHMW05 as a background well.

April 2019 Tunnel Well Temperature Profiles



September 2017 Tunnel Well Temperature Profiles



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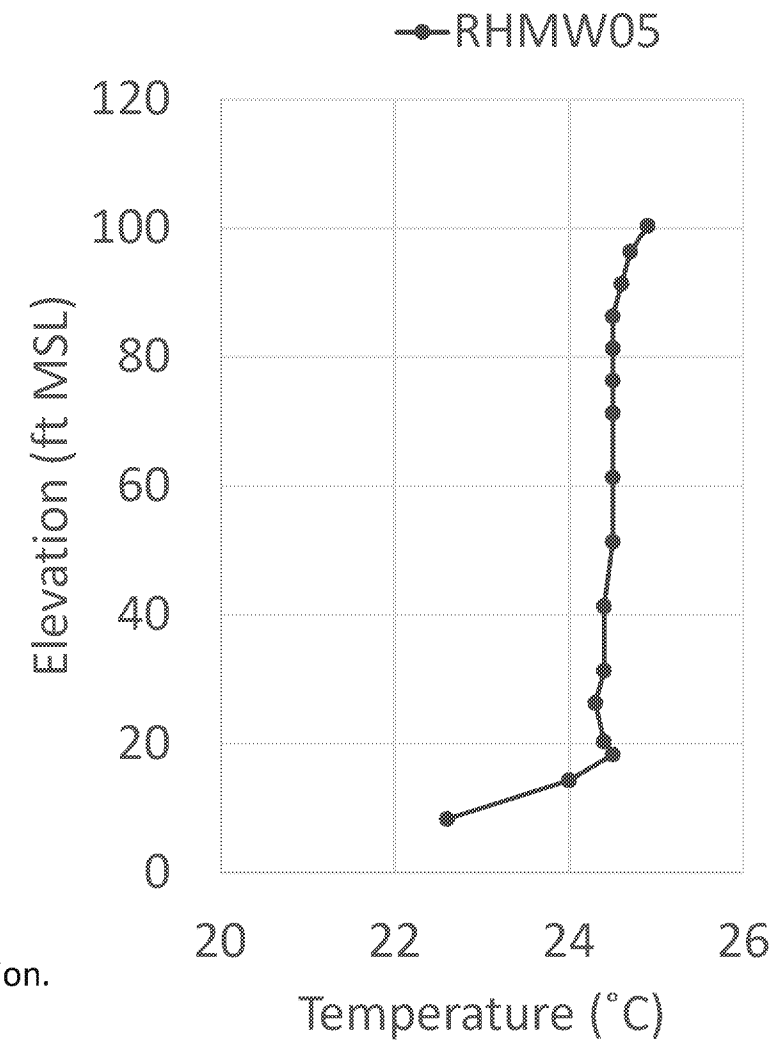
Unlike any other profile, RHMW05 is nearly isothermal with the water table

Could this be caused by air flow up the well casing from the screen to the lower tunnel?

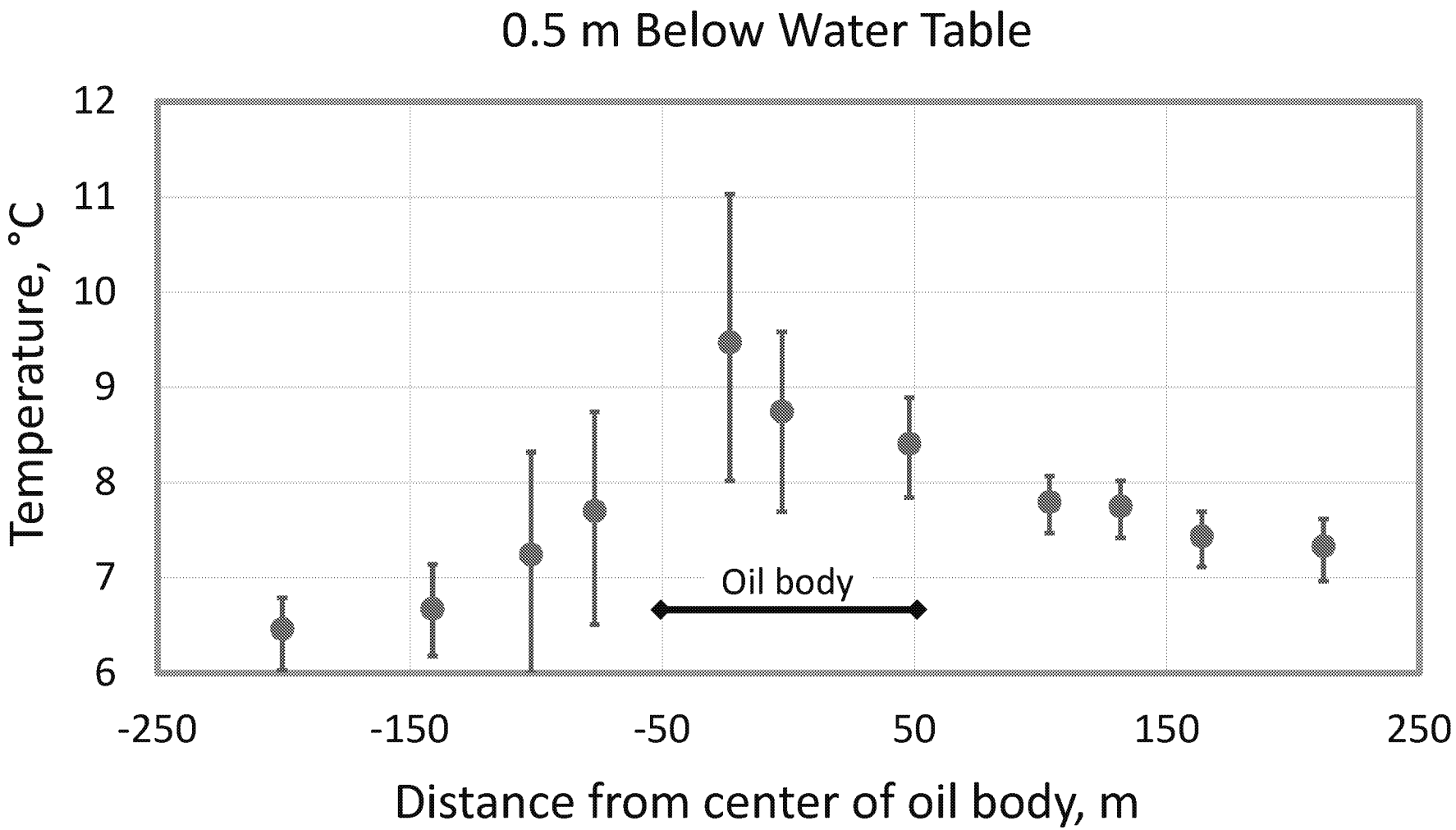
Discussed in CSM Appendix B.1, p. 1-3

- To prevent flow the wells were capped for 3 days before T measurements
- Wall and air T data were found to be comparable

Can these precautions eliminate the effect of long-term air flow inside the casing?



Bemidji groundwater temperatures were logged over a year or longer



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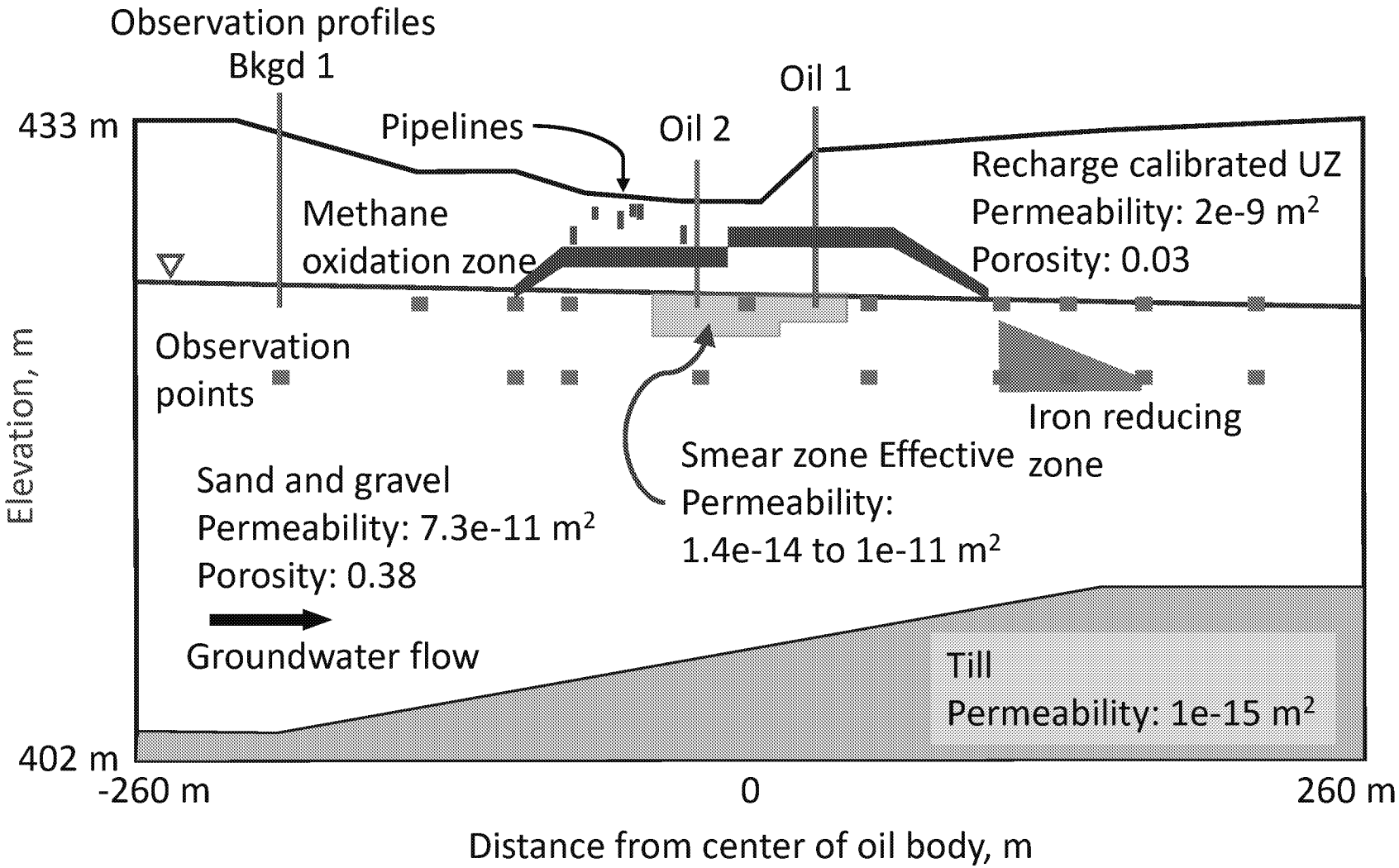
Heat transport model



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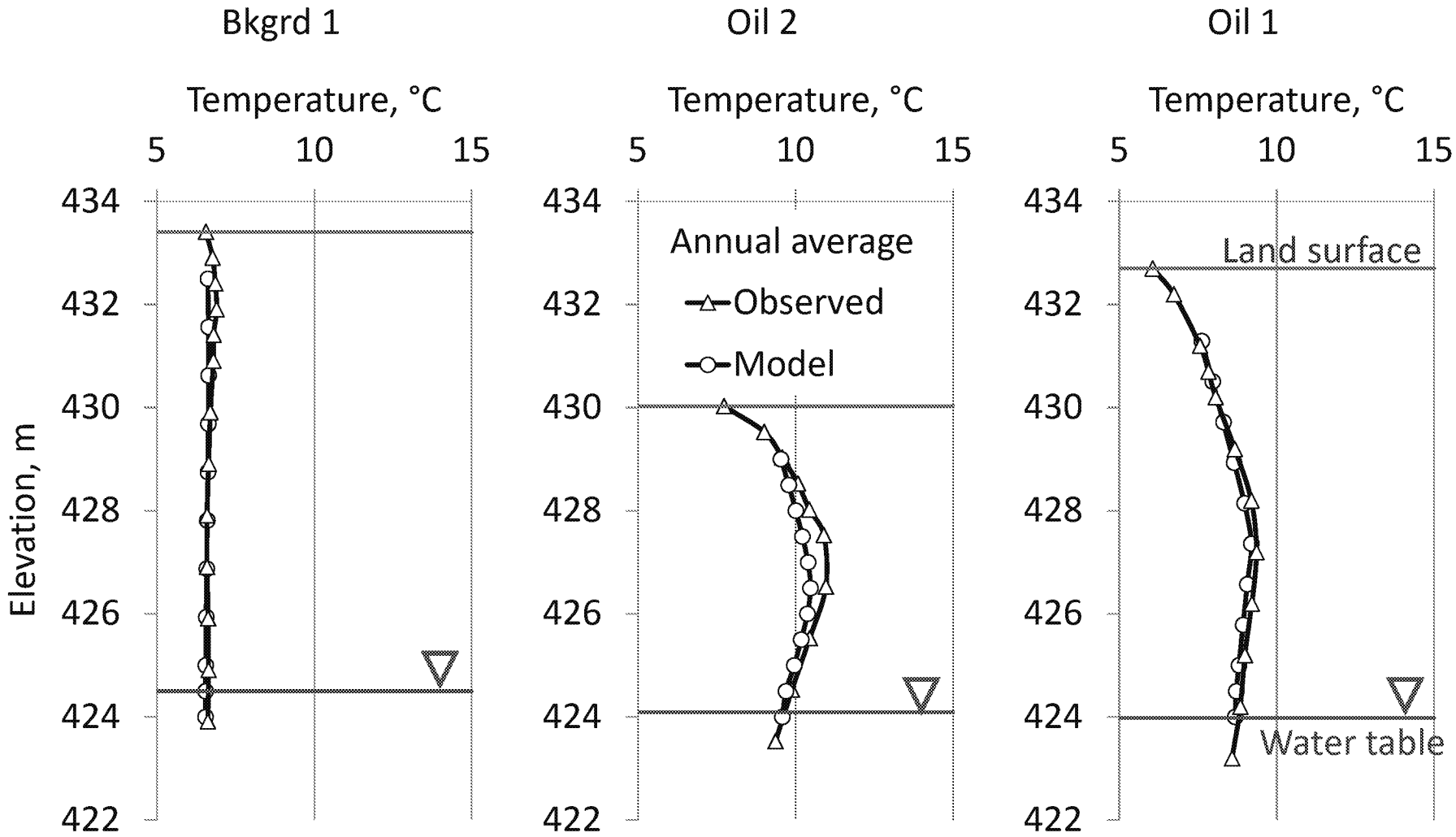
Model unsaturated zone temperatures are within <0.5 °C of observations



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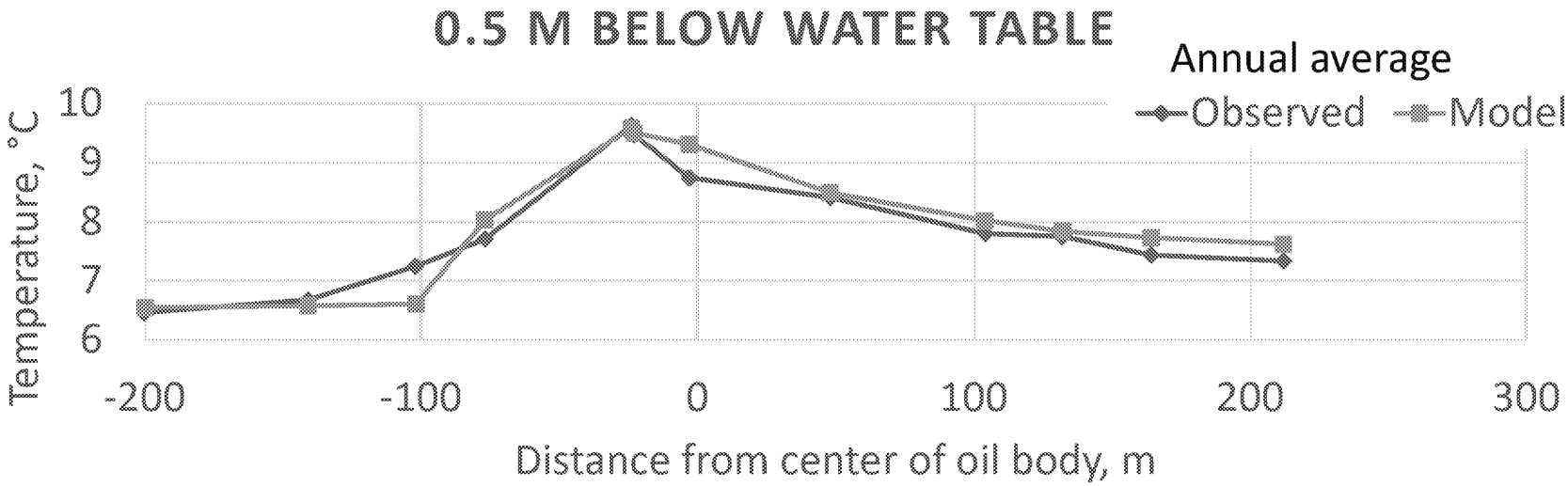
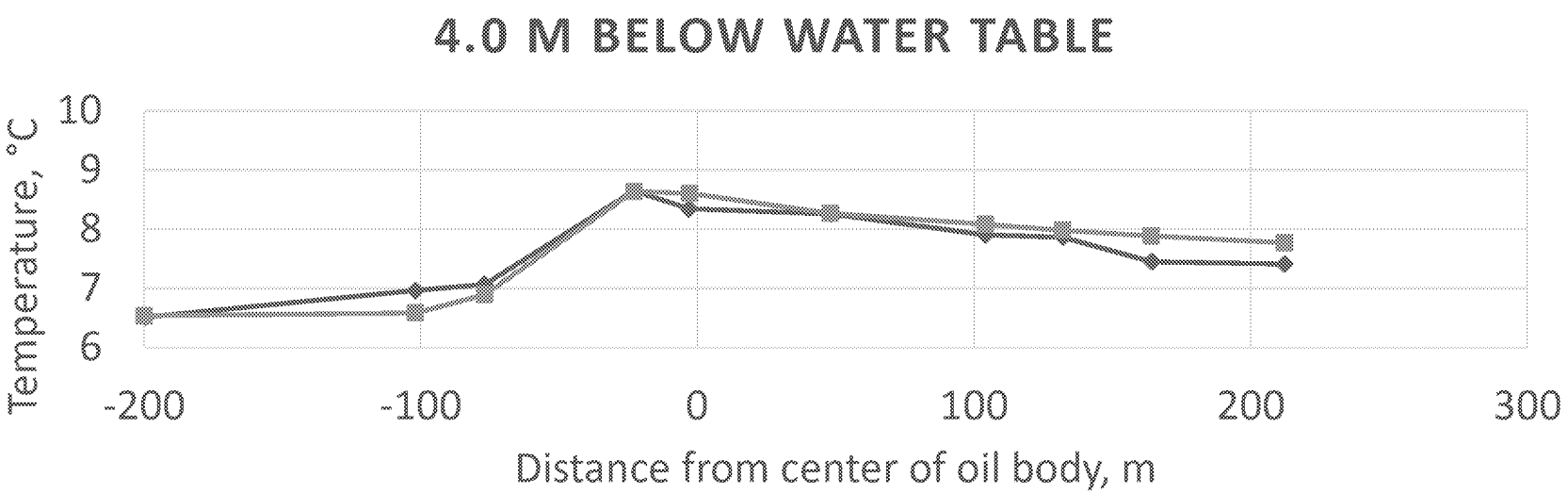
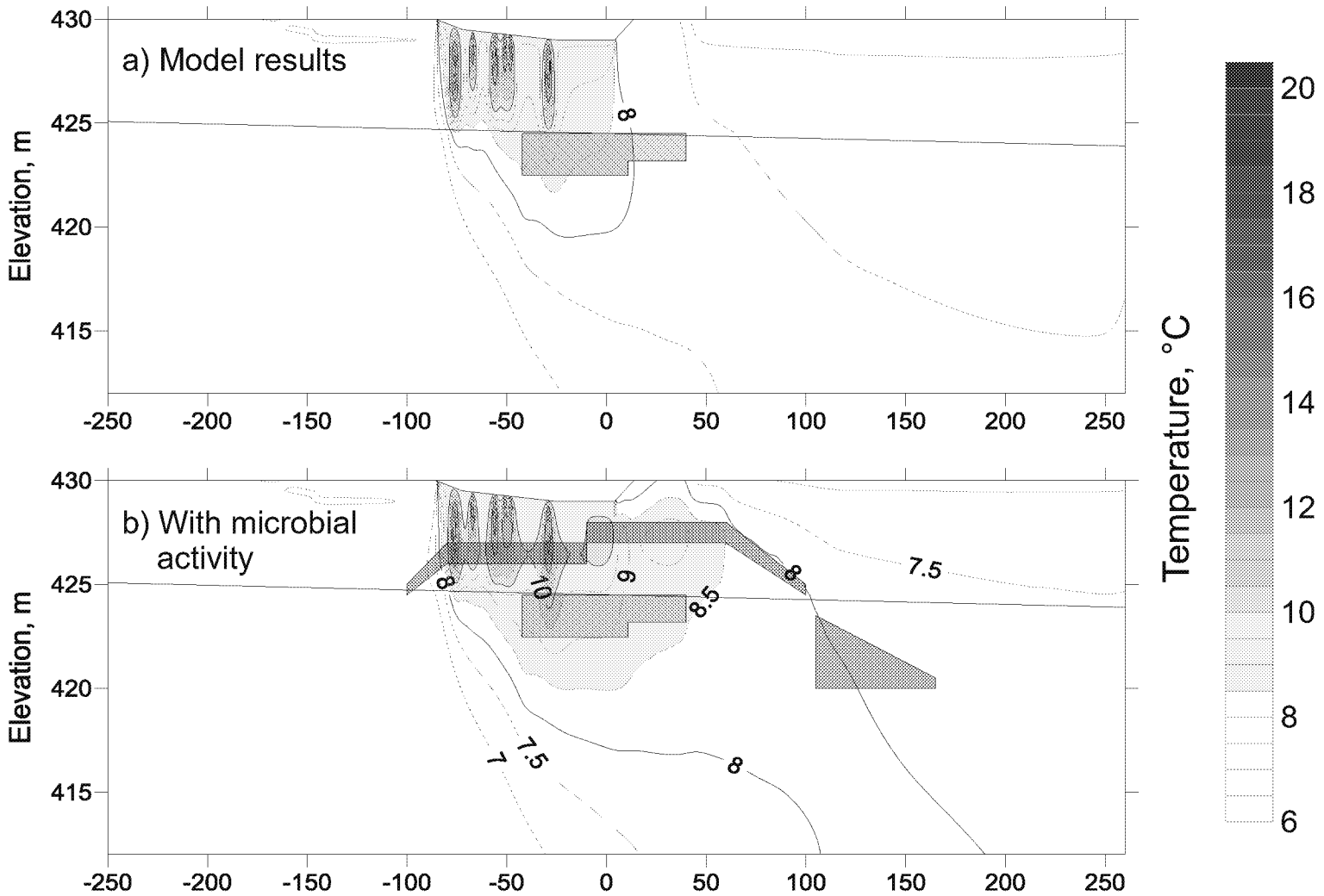
Modeled and measured groundwater temperatures are within 0.4 °C





The oil pipelines contribute half the observed heating



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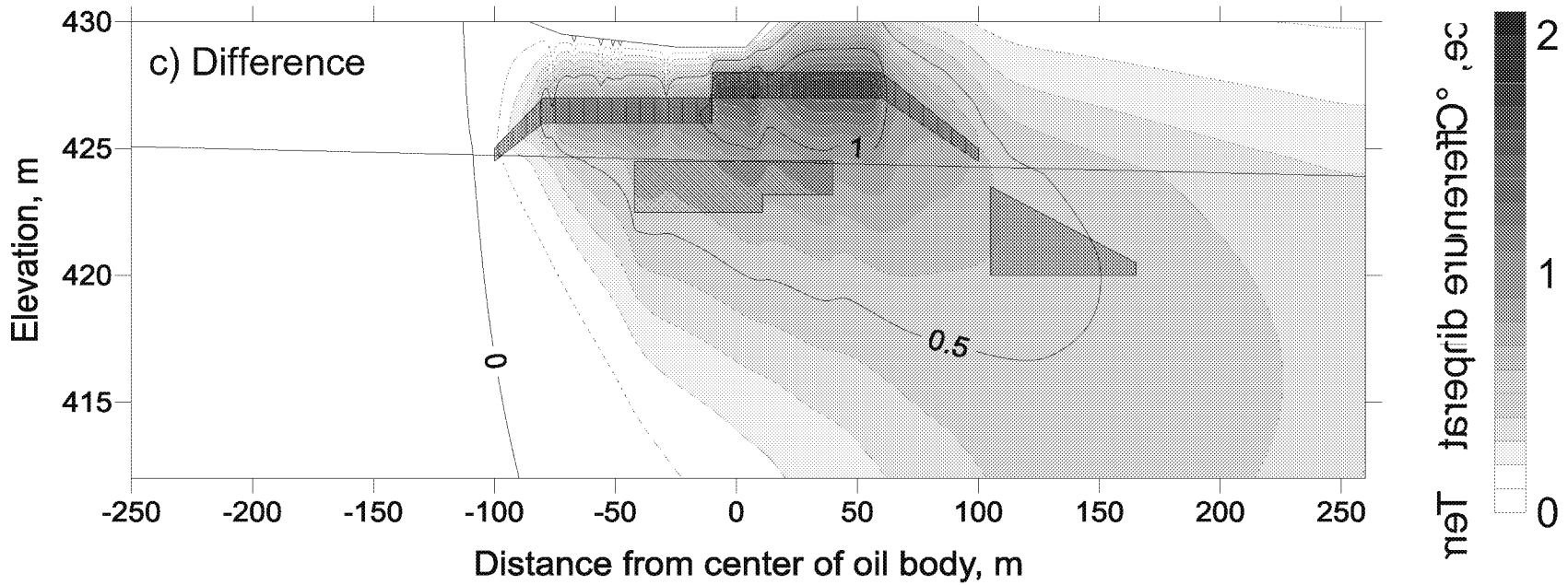
In the unsaturated zone, microbial heating increases temperatures 2°C above the pipelines alone



Conclusions

- Two peer reviewed studies of heating are based on data showing the heat is caused by methane oxidation
  - Heating caused by aerobic degradation has been described but not demonstrated in a known peer-reviewed publication
- Quantifying the microbial heat budget requires accounting for infrastructure and surface contributions
  - Choice of a background site is key